Implementation of Nuclear Construction Codes in Finland – experience from Olkiluoto 3 Project

NUCLEAR CONSTRUCTION CODES AROUND THE WORLD

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Content

- The Finnish regulatory framework
- Codes and standards in Nuclear civil construction in Finland
  - **ASCE**, American Society of Civil Engineers
  - **ASME**, American Society of Mechanical Engineers
  - **EN**, European Standards
  - **KTA**, Nuclear Safety Standards Commission in Germany
  - **RakMK**, Finnish Building Code
  - **RCC-CW**, Civil engineering works of NPP, **AFCEN**
  - **SFS**, Finnish Standards Association
- Combining design, product and execution standards in Finland
- Some experiences from Olkiluoto 3 (OL3) construction civil works
  - ASME criteria exceeded in inner containment liner

Finnish nuclear legislation and safety requirements

Nuclear Energy Act

- “nuclear energy utilisation shall be safe”; “licensee is responsible for safety”, other principal safety req’s (including security and on-site environmental protection)

Nuclear Energy Decree

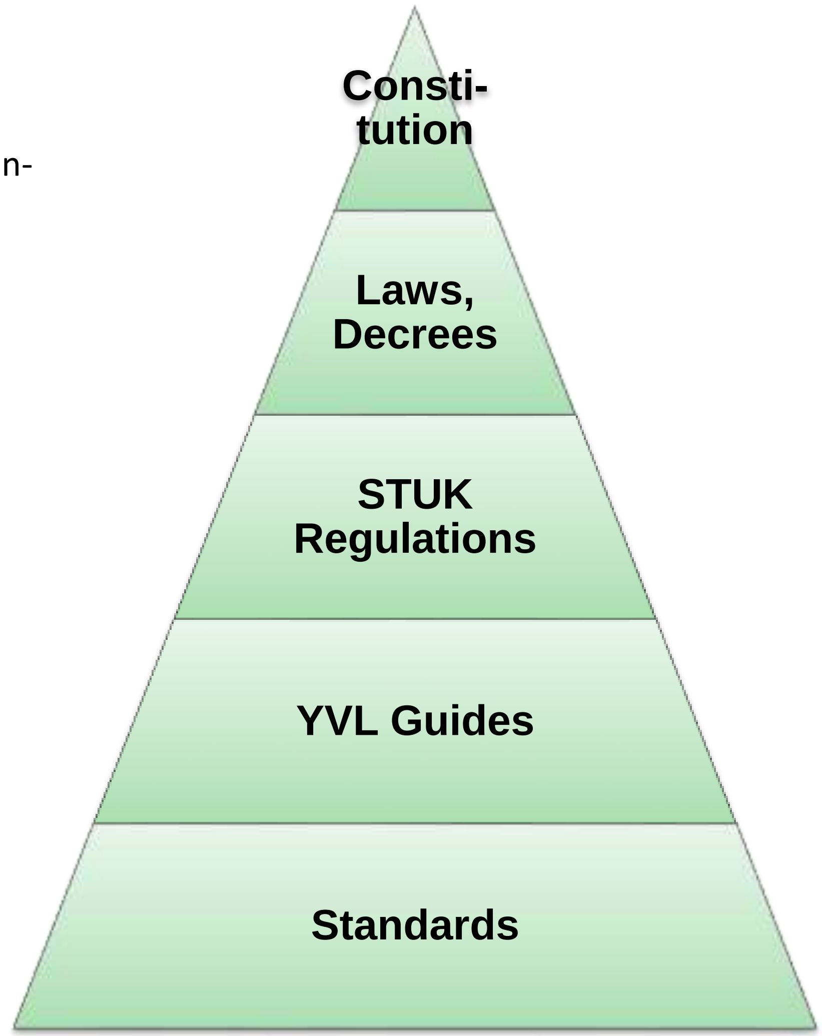
- administrative details for licensing and regulatory oversight
- radiological acceptance criteria

STUK Regulations

- mandatory requirements for Nuclear safety, Emergency preparedness, Nuclear security, Nuclear waste management, Safety of Mining and Milling Practices for Producing Uranium and Thorium
- general principles, fundamental technical requirements etc.

YVL Guides (YVL E.6 for civil works)

- status as Reg. Guides in USA
- detailed technical requirements, acceptable practices, guidance for licensee-STUK interaction, STUK’s oversight



Civil codes and standards in Finland / OL3

Commonly used in civil works of NPPs	OL3 civil construction

• Design:
– **ASME III Div 1** for load bearing part
– **ASME III Div 2** for leak tightness part of containment
– **ASCE 4-98, 43-05,** earthquake resistance design
– **KTA 3401**, liner structures of radioactive fuel pools
– **EN** and **RakMK**, post tensioning, reinforced concrete and conventional steel structures
– **RCC-CW,** code is under development for common European usage
  • Advanced coordination between nuclear design code and EN standards
	• Design:
	– **ASME** for containment liner and post-tensioning
	– **ASCE** for seismic capacity
	– **KTA** for pool liners
	– **EN standards** and **RakMK** for concrete and conventional steel structures
	  • National annex of EN 1992 (Eurocode 2) of Finland was not ready when the detail design of containments started
	  • Separate Appendix for detail parameters of EN 1992, ex. shear capacity rules stricter than in today's Finnish national annex

Civil codes and standards in Finland / OL3

Commonly used in civil works of NPPs	OL3 civil construction
• Material: – **EN** for concrete and steel structures – **EN/KTA** for liner structures – **STUK-YTO TR 210** for coatings in containment) • Guide is under development, in time will be replaced by Research report of Finnish Research Center (VTT) • Execution – **EN, KTA** • Inspection and testing – **ASME, EN** • Quality management – **EN ISO 9001:2000** all civil works – **IAEA 50-C-Q** nuclear safety related civil works	• Material: – **EN** for concrete and conventional steel structure – **EN/KTA** for containment and pool liners – **STUK-YTO TR 210** for coatings in containment) • Execution – **EN, KTA** • Inspection and testing – **ASME**, **EN** include NDT • Quality management – **EN ISO 9001:2000** – **IAEA 50-C-Q**

Design, product and execution standards referred in YVL E.6

STRUCTURAL DESIGN:
- EN 1990, Basis for structural design
- EN 1991, Actions of structures
- EN 1992, Concrete structures
- EN 1993, Steel structures
- EN 1994, Composite steel and concrete
- EN 1997, Geotechnical design

CONCRETING:
- EN 206-1, Concrete – Part 1: Specification, performance, production and conformity
- SFS 7022, application of EN 206-1 in Finland
- SFS-Manuals for testing

PRODUCTS, incl. TESTING:
- EN 10080, Steel for the reinforcement of concrete
- EN 10138, Prestressing steels

hENs, ETAGs and ETAs for construction products relevant for civil structures

CE

CONCRETE COMPONENTS:
- EN197-1, Cement,
- EN 12620, Agregate
- EN 934-2, Admixtures
- EN 450, Fly ash
- EN 13623, Silica
- EN 15167, Granulated blast furnace slag
- EN 1008, Water

CE

CIVIL WORKS:
- EN 13670, Execution of concrete structures
- SFS 5975, application of EN 13670 in Finland
- EN 1090, Execution of steel and aluminum structures

Some experiences from OL3 construction

Post tensioning system

– mock-ups, flexible post tensioning schedule

Dome

– mock-ups

Brackets of polar crane

– shear capacity

Steel platforms

– exceeded safety importance

Fire at the site

– damage study and repair plans

Liner manufacturing

– non-conformances in welding and oversight

Gusset area

– mock-ups, concrete mix

Base slab concreting

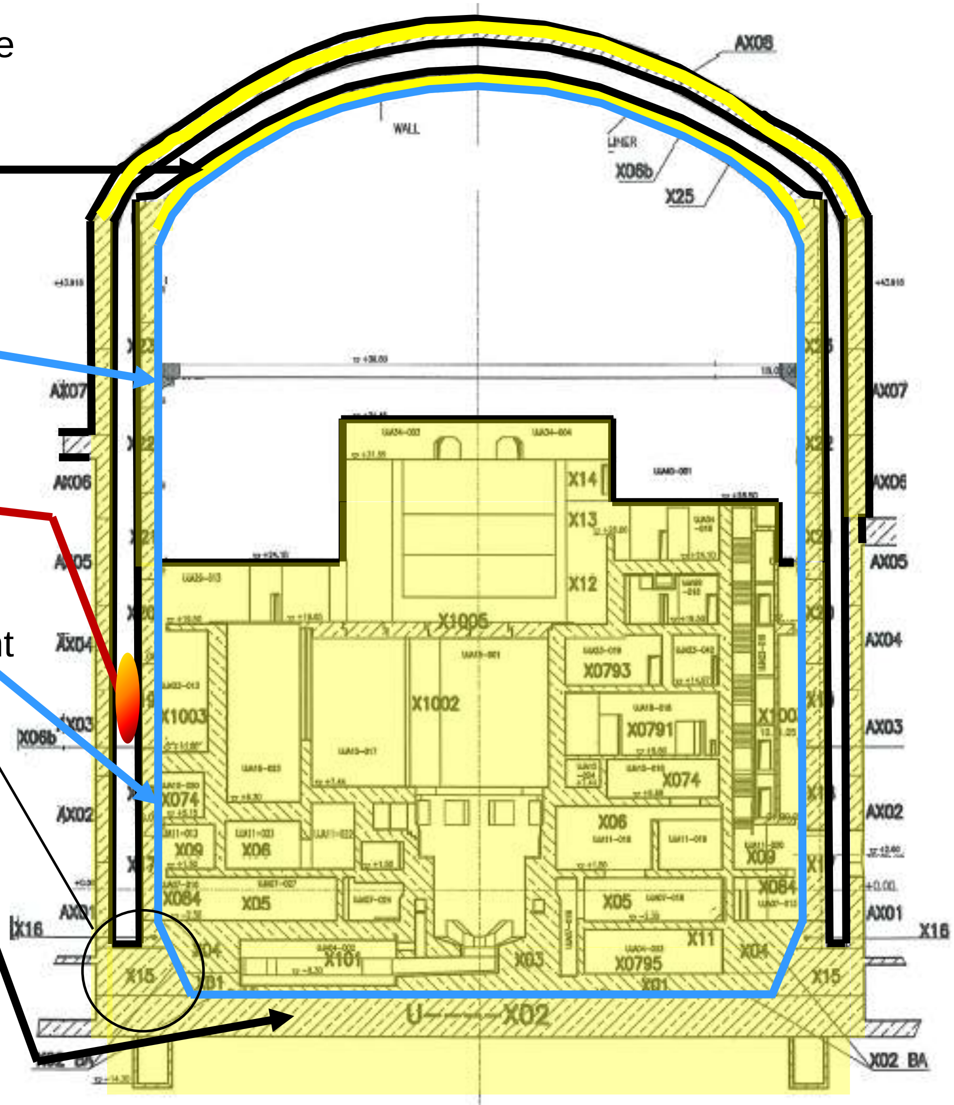
– water/cement ratio, lifetime requirements

Rock excavation works

– misfired explosives at channel excavation

Safety culture at site

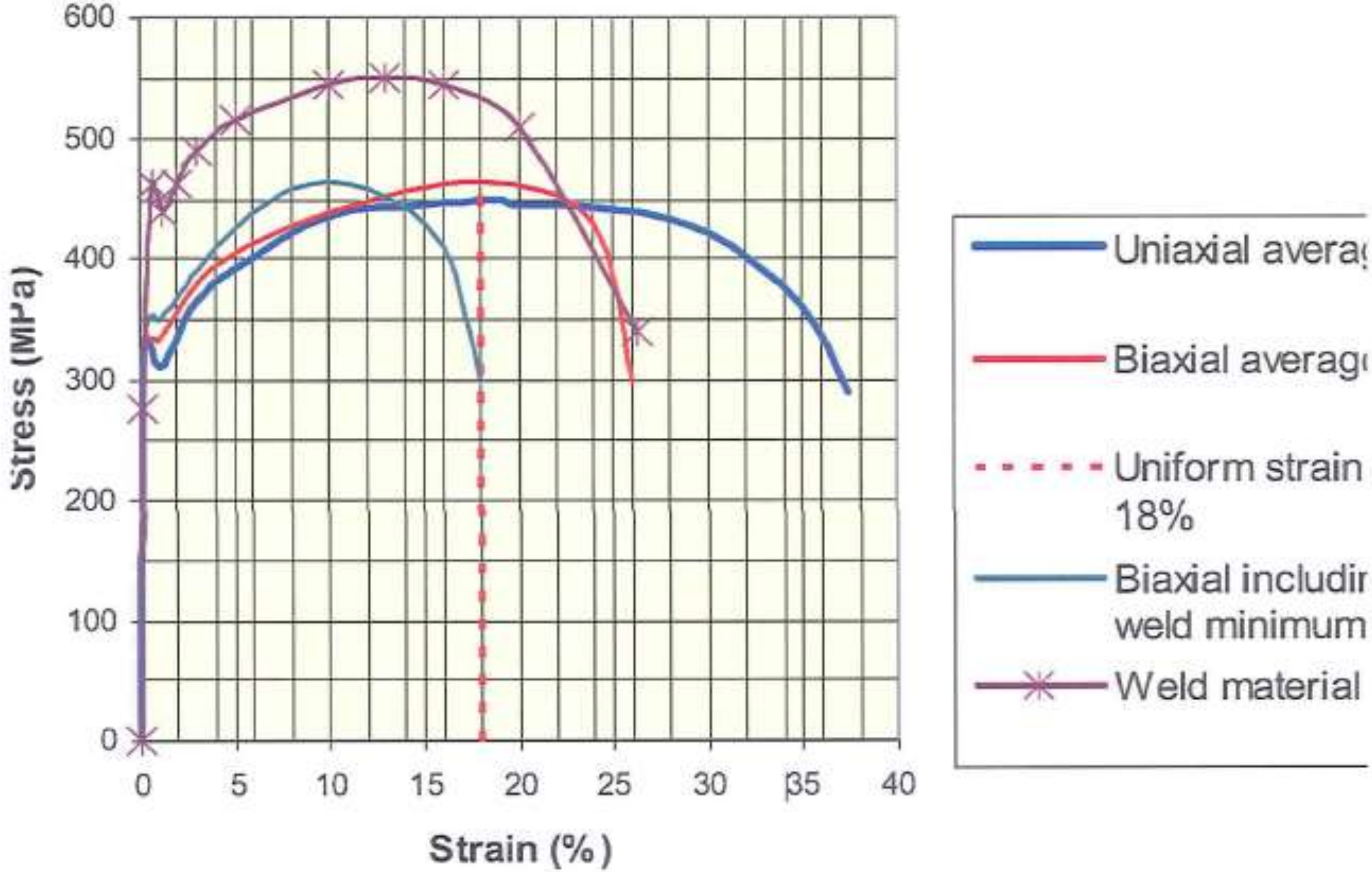
– multinational site, many contractors



Liner Strains of inner containment exceeding ASME limits

- TVO and AREVA proposed new site-specific allowable liner strain values
  - more analyses: non-conformance specific studies
  - more tests: tangential shear and biaxial in-plane tests
  - In-Service Inspection: plan and measurements for containment liner
  - justification report: STUK's acceptance required for replacing ASME Code -> allowable liner strain values based on analysis, testing and in-service inspections
- Not only a local problem
- Compressive membrane and combined membrane and bending strains exceeded more
- Also tensile strains exceeded
- Final approval based on pressure and leak-tightness tests

Assessment of Failure strains



Study of post critical strains

Critical effective plastic strain ε(failure) = ε(uniaxial)·f1·f2·f3·f4

- f1: multi-axial stress-state
- f2: sophistication of the analysis model
- f3: variable material properties
- f4: knock-down factor for corrosion (=1 with Zink-silicate protection)

- Cylinder: ε(failure) = 35 % · 0,69 · 0,5 · 1 · 1 = 12,1 %
- Dome: ε(failure) = 35 % · 0,61 · 0,5 · 1 · 1 = 10,8 %
- Uniform strain, neglecting residual part of stress-strain curve: ε(failure) = 18 % · f2 · f3 · f4 = 18 % · 0,4 · 1 · 1 = **7,2 %**
- Approvable post critical strains of ASME 14 ‰ to be increased up to **72 ‰** = 3 x (Failure strain of average biaxial tests)

New values replacing ASME limits

- ASME -> New values for limitation of strains based on analysis and testing (m=membrane, b=bending):
  - NOC, factored, membrane 2 ‰ -> 12 ‰, m+b 4 ‰ -> 24 ‰
  - NOC, service, membrane 2 ‰ -> 8 ‰, m+b 4 ‰ -> 16 ‰
  - LOCA, factored, membrane 5 ‰ -> 20 ‰, m+b 14 ‰ -> 50 ‰
  - LOCA, service, membrane 3 ‰ -> 12 ‰, m+b 10 ‰ -> 36 ‰
  - SA, factored, membrane 7 ‰ -> 25 ‰, m+b 18 ‰ -> 60 ‰
  - SA, service, membrane 4 ‰ -> 15 ‰, m+b 13 ‰ -> 45 ‰
- In-service inspection for containment liner required
  - Inspection plan enforced by smart-tape solution with local stretch slips
- Inner containment passed pressure and leak-tightness tests
  - Leak-tightness test to be updated at the end of commissioning because of long term construction
- STUK has approved new criteria beyond ASME criteria
  - Inner containment fulfils all STUK regulations

Thank You!

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